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Applying QR Codes in Facilitating Mathematics and Informatics Education

Abstract

QR codes are usually discussed in the context of mobile learning. In our article, we show other opportunities of their use with special focus on mathematics and informatics education and its methodology. Appropriately placed QR codes can, for example, be applied to create a feedback for both students and teachers, as an additional source of problems in a problem solver or a worksheet, or as an input gate to a didactic game. The addressees use their smartphones to read their selected QR code. The code refers to a file containing the data files predesigned and stored by their educator or the author of learning materials. The data are then used in accordance with their educator's instruction. Similarly, a QR code can link additional information sources in a worksheet or open the student's gate to the course/instructor evaluation. In the paper, we portray such an approach using examples from various fields of mathematics, statistics, and databases. Finally, we discuss advantages and disadvantages of this approach.

K e y w o r d s: QR code, educational technology, mobile learning, distance education

Introduction

Schools have to respond to the development of technology. In our article, we study the application of QR codes in education. Various forms in which they may add a value to teaching and learning processes are identified and exemplified.

According to Andrew Ramsden (2008, p. 2), under the QR (Quick Response) code we understand "a two dimension bar code that can be read on devices such as a mobile device (camera phone) or a laptop computer which, once accessed, will allow you to complete an action." The code, therefore, primarily serves as an input to a mobile device – a smartphone or a laptop. The device reads and encodes it. As a final result, the message hidden in the QR code activates the receiving device and ignites its activity. The activity is usually stored on the Internet.

From a general point of view, the entire process consists of three basic steps:

- The mobile phone contains an application capable of recognising and reading QR codes. When the application is running and the device's camera is pointed to a QR code, the encoded information enters the device.
- The device accesses the file specified by the code. (The file must be available on the Internet and its URL address must coincide with the result of decoding.) The application opens the file. In accordance with the type of the file, it may display its data (text, pictures, videos, etc.) or start executing the stored programme.
- In the latter case, the programme takes control over the device (over its screen, keyboard, etc.) If the programme is interactive, the user can communicate with it.

For educators, it means that they can exploit the QR codes in two basic ways. First, they can prepare data files in which announcements of any kind (time schedules, notices, assignments, and so on) are stored. This approach exploits only first two steps specified above. The gained information is static and can be used primarily in the read-only mode.

In our article, we concentrate on the second option – the QR code activates interactions between the programme and its user. This option makes it possible to form an educational environment for active learning. When properly designed and implemented, learners can be instructed by means of, for example, strategies typical of constructivist methodologies i.e. they can be guided to collaborate in building their knowledge (Silberman, 1996; Tóthová, Kostrub, & Ferková, 2017).

Using QR Codes in Educational Applications: A Brief Overview

The authors support the standpoint of Hsin Chih Lai et al. (2013), who understand the use of QR codes in education as a potential expansion of the learning space. The expansion moves to all directions: time, space, and type of the delivered "lessons." Moving in time and space means that anyone reading the barcode can reach its content. The type of delivered material is only limited by the available IT. It can consist of text, sound, video, interaction with the user, etc. Advanced versions can ignite procedures like augmented reality, virtual environments, etc. According to Sabrina Leone (2015, p. 2628), "since learning takes place in many contexts, formal, non-formal and informal, inclusive and quality education become synonyms and are vital for the development of more inclusive societies."

Traditionally, education is performed in classrooms. Even in this environment, QR-based approaches have a quite long tradition (see, for example, Curtis et al., 2002). However, their intensive exploitation is a recent phenomenon related to the widespread use of needed technology. Teaching and learning are moved beyond their traditional limits, and the reasons for it are obvious: appropriate technology is now easily available and less expensive, and with its wider saturation in schools the educators are learning its capability, including its advantages and drawbacks.

However, the technology itself does not suffice. The concept is not well known yet (Chicioreanu, Bilal, & Butnariu, 2015). The educators must be not only willing to use it (Abas, Yahya, & Kamaruddin, 2015), but also adequately prepared, that is, trained. The instructions like that of Ramsden (2008) explain the process of the implementation, but do not motivate teachers enough to create their own applications. Below we show how such environments can be prepared by professionals or passionate laymen and later exploited by anyone. We are supporters of the idea that – similarly to the textbook preparation – QR code based applications should be made by highly qualified individuals and teams to ensure their quality. Teodora Daniela Chicioreanu, Essaid Bilal, & Monica Butnariu (2015) exemplify parts of learning processes which can be transmitted using QR codes:

- the educator's contact information;
- access to required or additional resources;
- syllabi, course handouts, assignments, and tutorials;
- tests and their sample solutions; and
- social and community activities (team-building, invitations to school events, polls and voting, virtual tours, …).

The last item illustrates how outdoor activities can be promoted using QR codes. A typical example is posting QR code based information at historical monuments or other points of interest (Bohumelová & Hvorecký, 2015). Their

activation delivers relevant information to the visitors, often in several forms and formats. The educational value of such an approach is indisputable and presents QR codes as a considerable tool for life-long education.

QR Codes as Links to Learning Materials

The main feature of QR codes is their ability to refer to distant (Internet-based) information sources. This attribute can be utilised by educators in various situations. The authors employed the access to Internet information via QR addressing different categories of audience. Below are typical examples.

Teacher Manual

The book by Lilla Koreňová (2015) explores the use of QR codes for addressing external information that can hardly be reached in traditional textbooks. Her book addresses in-service and pre-service mathematics teachers. Due to QR codes, she can consider animation as a supportive tool in her explanations – something impossible in standard textbooks. Because of low familiarity with this concept among older teachers, the book introduction also explains ways of purchasing and implementing relevant software for mobile phones. It addresses two most popular systems – Android and iPhone – as well as a desktop QR code reader.

The book also discusses a variety of external educational software products for pupils and students. Due to their easy reach via QR codes, the teachers can quickly access them and test their relevance to their educational aims and methods.

For a full use of textbook ideas, Geogebra software is required. The text contains instructions on reaching and implementing it, too. The process can be done using a QR code (see Figure 1).

Figure 1. QR code support for installing Geogebra.

S o u r c e : Koreňová, 2015.

Geogebra itself contains many problems which can be incorporated by teachers in their education. The textbook refers to them, too (see Figure 2).

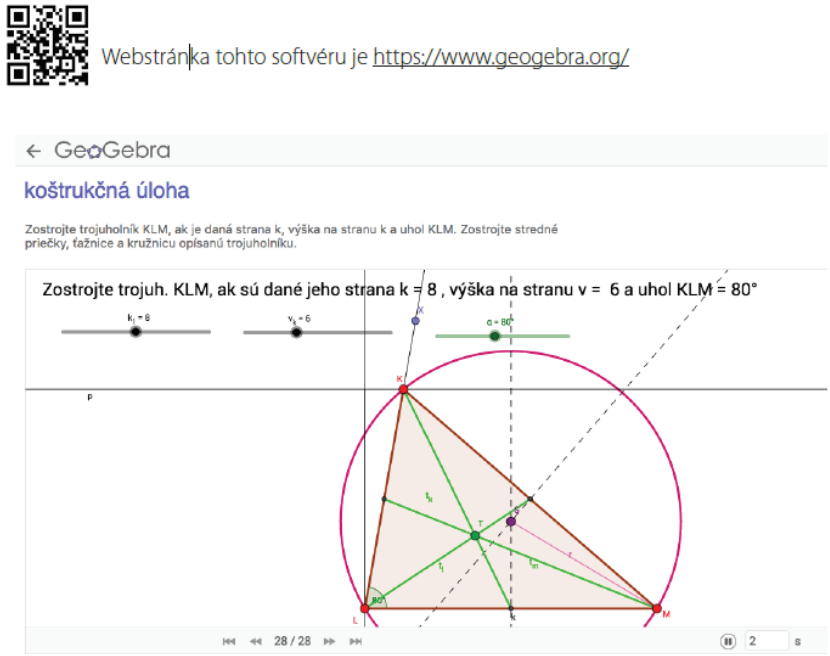


Figure 2. An animated construction problem in Geogebra.

S o u r c e : Koreňová, 2015.

The QR codes may also address links on the portal GeoGebratube. One can benefit from these ready-to-apply applets.

Using a Graphic Calculator as a Student's Individual Display

The teachers can prepare their own problems by themselves. In this case, they also need a QR code generator – the software encrypting a text (usually an URL address) into its QR code. The CASIO Classwiz calculator includes it in its standard software. First, the teacher prepares the problem by himself or herself to a state in which his or her students' activity should begin. Then, he or she produces its QR code. After its encoding, the data file stores the current status of the Classwiz screen. As CASIO Classwiz is not a graphic calculator, the problem is "frozen" in its numerical format. It can be unfrozen and transferred to a graphic device by anyone who reads it by his or her smartphone or tablet. The file is restored in its memory, and the user can continue its solution from the given moment.

Figure 3 shows a solution of the cubic equation $x^3 + 507x^2 + 62370x = 0$. Then, the user presses SHIFT+OPTN to read the code. The screen shows the graph (see Figure 3).

The same approach can be applied for various purposes. As mentioned above, Figure 3 shows a graphic solution of the cubic equation. The solution can continue by determining values of the roots, by finding a local maximum and a local minimum of the function within a specified interval, etc. The partially solved problems can be used during tests and exams. In these situations, the prepared files allow all students to use the same data sets. This is important when a file is extensive e.g. in problems in statistics.

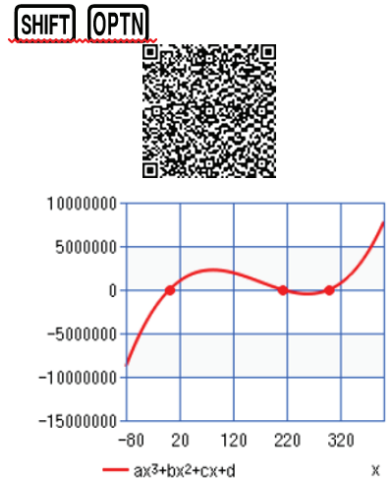


Figure 3. Use of a QR code in Classwiz.

S o u r c e : Own work.

Sets of QR Codes: Towards Complex Solutions

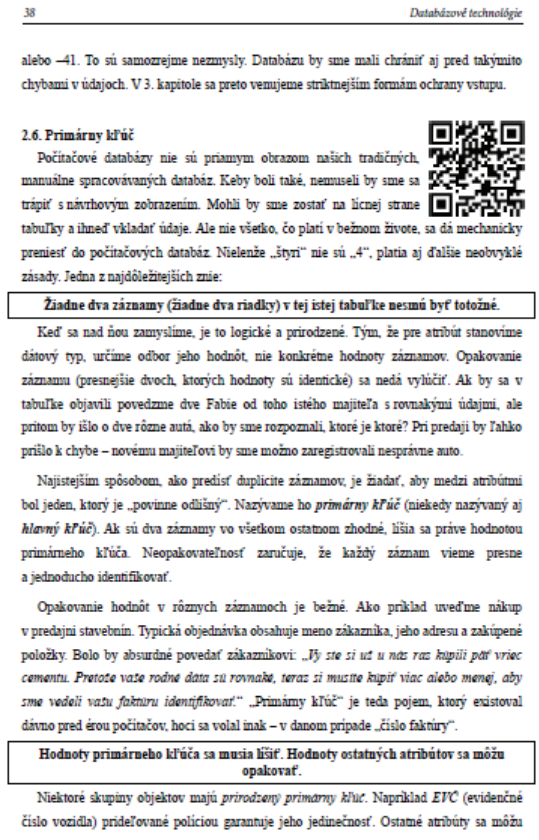
As has been indicated above, there are many ways of applying QR codes to facilitate education. All examples were one-purpose. Their only role is to deliver its corresponding content and to evoke an educational activity. At the same time, sets of QR codes can form a complex environment addressing an entire subject. Then, the individual files address a learning unit but their contextual meaning is changing because it builds the course context. We illustrate the idea with the following example – the use of a complex system of self-supporting electronic tools including QR code based access as its part.

The educational process is formed around a textbook (Hvorecký, 2013a). It addresses an introductory database course for students of management. The course is taken by both regular and external students. While the regular students attend lectures and work in laboratories under lecturers' guidance, the external

students miss these interpersonal contacts. Preparing the textbook came up as the very traditional step to enhance their learning – to write a supplementary text. Then, a question rose: The students need their computer (or at least a regular access to it) to study a database course. Can we find additional computer-based methods to facilitate their study? The implemented solution is complex; access using QR codes is just a part of it.

As a result of these considerations, the textbook contains several hundred problems. In order to make the basic text shorter (it has got almost 300 pages), unsolved problems are collected in a separate booklet (Hvorecký, 2013b). The problem solver itself is about 100 pages long because it contains more than 200 problems of different levels of difficulty.

Database problems require large data sets. Typing them would be time-consuming. There certainly would appear unintentional errors as a result of manual typing. To avoid the danger, a USB memory key has been attached to the problem solver. It contains databases necessary to all problems.



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alebo –41. To sú samozrejme nezmysly. Databázu by sme mali chrániť aj pred takýmito chybami v údajoch. V 3. kapitole sa preto venujeme striktnejším formám ochrany vstupu.

2.6. Primárny kľúč

Počítačové databázy nie sú priamym obrazom našich tradičných, manuálne spracovávaných databáz. Keby boli také, nemuseli by sme sa trápiť s návrhovým zobrazením. Mohli by sme zostať na lícnej strane tabuľky a ihneď vkladať údaje. Ale nie všetko, čo platí v bežnom živote, sa dá mechanicky preniesť do počítačových databáz. Nielenže „štyri" nie sú „4", platia aj ďalšie neobvyklé zásady. Jedna z najdôležitejších znie:

Žiadne dva záznamy (žiadne dva riadky) v tej istej tabuľke nesmú byť totožné.

Keď sa nad ňou zamyslíme, je to logické a prirodzené. Tým, že pre atribút stanovíme dátový typ, určíme odbor jeho hodnôt, nie konkrétne hodnoty záznamov. Opakovanie záznamu (presnejšie dvoch, ktorých hodnoty sú identické) sa nedá vylúčiť. Ak by sa v tabuľke objavili povedzme dve Fabie od toho istého majiteľa s rovnakými údajmi, ale pritom by išlo o dve rôzne autá, ako by sme rozpoznali, ktoré je ktoré? Pri predaji by ľahko prišlo k chybe – novému majiteľovi by sme možno zaregistrovali nesprávne auto.

Najistejším spôsobom, ako predísť duplicite záznamov, je žiadať, aby medzi atribútmi bol jeden, ktorý je „povinne odlišný". Nazývame ho ***primárny kľúč*** (niekedy nazývaný aj ***hlavný kľúč***). Ak sú dva záznamy vo všetkom ostatnom zhodné, líšia sa práve hodnotou primárneho kľúča. Neopakovateľnosť zaručuje, že každý záznam vieme presne a jednoducho identifikovať.

Opakovanie hodnôt v rôznych záznamoch je bežné. Ako príklad uveďme nákup v predajni stavebnín. Typická objednávka obsahuje meno zákazníka, jeho adresu a zakúpené položky. Bolo by absurdné povedať zákazníkovi: *„Vy ste si už u nás raz kúpili päť vriec cementu. Pretože vaše rodné dáta sú rovnaké, teraz si musíte kúpiť viac alebo menej, aby sme vedeli vašu faktúru identifikovať."* „Primárny kľúč" je teda pojem, ktorý existoval dávno pred érou počítačov, hoci sa volal inak – v danom prípade „číslo faktúry".

Hodnoty primárneho kľúča sa musia líšiť. Hodnoty ostatných atribútov sa môžu opakovať.

Niektoré skupiny objektov majú *prirodzený primárny kľúč*. Napríklad *EVČ* (evidenčné číslo vozidla) prideľované políciou garantuje jeho jedinečnosť. Ostatné atribúty sa môžu

Figure 4. A textbook page with a QR code to a video.

S o u r c e : Hvorecký, 2013a.

The USB key contains more than just necessary data. The solutions are "partially complete" to the degree that allows the students to concentrate exclusively on their final parts – the study material delivered in the given chapter. For example, when they are asked to build a user-friendly communication, the "raw" database is formally complete but it would require a database specialist to exploit it. As a result, the student can concentrate on building the particular "clearly isolated" task – building a user-friendly communication of a completed database. The problems can be solved using analogy with comparable problems presented in the textbook. The chapter numbering in the textbook and in the problem solver are identical, i.e. finding relevant solved problems to unsolved ones is easy.

The database courses are generally accepted as difficult ones. It is based on the fact that working with the database management system (an authoring tool for building databases) is difficult. The solution requires a lot of attention; the probability of unintentional errors is rather high. All detailed steps must be done with caution and tested using large input data sets. The number of these technicalities can overwhelm their readers, and they can easily become lost. To help our students understand the problem at both formal and intuitive levels, new knowledge is also delivered using two formats. The explicit, exact, and detailed description is done in the textbook. Less formal (tacit) knowledge is provided via video lectures. The reference to the particular video is made by a QR code. Its encoded link refers to YouTube (see Figure 5).

In total, thirty videos done by the author were shot and posted on YouTube. In the videos, the author demonstrates slides and speaks about the particular problem in a rather informal style. The videos cover the course sections which – in accordance with the author's experience – represent the most difficult sections of the course. Their duration is four to ten minutes. All videos are stored on YouTube and their corresponding slides at the USB memory key together with the "half-completed" databases.

Figure 5. The title slide of PowerPoint file with the QR code and URL address of video lecture.

Source: Own work.

The list of course supporting materials is as follows:

- a textbook with thirty QR codes: the code is placed next to the piece of knowledge the lecture explains;
- a problem solver: a booklet with about two hundred problems to be solved using MS Access;
- a USB memory key: a standard device with two file folders – the first one contains databases needed for problems presented in the problem solver, and the second one contains PowerPoint slides used in the videos;
- two hundred MS Access databases (one for each problem): for users' quick orientation, their names are based on the numbering of problems in the problem solver; and
- thirty PowerPoint files with slides: their names are based on the page number in the textbook with the relevant QR code (the first slide contains the same QR code and the URL address at YouTube – see Figure 5).

All this indicates that the set of material can be used for any cohort of novices who are interested in database design and implementation. The methodology was also tested on a group of pre-service students of informatics (Hvorecký, Drlík, & Munk, 2010). The outcomes were highly positive.

Conclusion

QR codes offer numerous ways in which the teaching and learning materials can be facilitated. Many positive examples in the previous sections demonstrate it. At the same time, no technology has been – and will ever be – the saviour of education. For that reason, we would like to point to the potential risks of using QR codes.

First, the success in education strongly depends on the personality of the teacher. He or she has to know when to use this technology and when not to. There are moments during the learning process when the support from a knowledgeable person is irreplaceable. As Hvorecký and Koreňová (2018) show, there are ways of reducing them and letting the learner go alone. Again, there has to be a sufficient amount of learning material of good quality.

Then, there can be problems with technology. The work with QR codes presumes the access to the Internet. Without a fast connection, the communication can be limited, with can have negative consequences for the learners' motivation. In addition to that, the quick development of information technology can result in some application's inability to run on the newest devices (due to the updates of hardware, software, operating system, programming languages, and/or other factors).

It also means that the authors of QR-using applications must pay attention to these innovations, and upgrade their teaching and learning materials, too. As the upgrading process is time-consuming, they should discuss the advantages and drawbacks of technology use, especially when they plan to design and develop their applications for long-time exploitation.

All of it implies that QR codes are excellent tools but – as everything in our contemporary society – keeping them alive requires regular and cautious maintenance.

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Stosowanie kodów QR w stymulowaniu edukacji matematycznej i informatycznej

S t r e s z c z e n i e

Temat kodów QR porusza się w kontekście uczenia się z wykorzystaniem aplikacji mobilnych. W artykule przedstawiono inne możliwości wykorzystania tych kodów z podkreśleniem edukacji matematycznej i informatycznej oraz ich metodologii. Kody QR, właściwie umiejscowione, mogą być na przykład użyte w tworzeniu informacji zwrotnej dla zarówno uczniów, jak i nauczycieli, jako dodatkowe źródło zadań problemowych w aplikacjach nauczających rozwiązywania problemów lub kartach zadań, lub też jako bramka informacji w grze dydaktycznej. Uczniowie używają smartfonów, by przeczytać wybrany kod QR. Kod odnosi się do katalogu zawierającego pliki z danymi wcześniej przygotowanymi oraz zapisanymi przez nauczyciela lub twórcę materiałów dydaktycznych. Dane te są następnie wykorzystywane zgodnie z instrukcją nauczyciela. Kod QR może również służyć do powiązania źródeł dodatkowej informacji na karcie pracy lub otworzyć uczniowi bramkę umożliwiającą ewaluację kursu lub wydanie oceny przez instruktora. W artykule przedstawiono przykład takiego podejścia z różnych obszarów matematyki, statystyki oraz baz danych. Na zakończenie omówiono zalety i wady takiego podejścia.

S ł o w a k l u c z o w e: kod QR, informatyka, uczenie się z wykorzystaniem aplikacji mobilnych, uczenie się na odległość

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Применение QR-кодов в обучении математике и информатике

Аннотация

QR-коды обычно обсуждаются в контексте мобильного обучения. В нашей презентации мы показываем другие возможности их использования с акцентом на образовании в области математики и информатики и его методологии. Надлежащим образом размещенные QR-коды могут, например, использоваться для создания обратной связи, как для учащихся, так и для преподавателей, в качестве дополнительного источника проблем для решения на листе или в качестве начала дидактической игры. Адресаты используют свои смартфоны, чтобы прочитать выбранный QR-код. Код относится к файлу, содержащему данные, предварительно разработанные и сохраненные преподавателем или автором учебных материалов. Затем данные используются в соответствии с инструкцией преподавателя. Аналогичным образом, QR-код может связывать дополнительные источники информации на рабочем листе или открывать доступ студента к оценке курса / преподавателя. В статье мы иллюстрируем такой подход, используя примеры из различных областей математики, статистики и баз данных. В заключении мы обсуждаем преимущества и недостатки данного подхода.

Ключевые слова: QR-код, Образовательные технологии, Мобильное обучение, Дистанционное обучение

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Aplicación de códigos QR en la adquisición de la Educación Matemática e Informática

Resumen

El debate de los códigos QR suele tener lugar generalmente en el contexto del aprendizaje móvil. En nuestro trabajo, mostramos otras oportunidades de su explotación poniendo el acento en la Educación Matemática e Informática y su metodología. Los códigos QR empleados apropiadamente pueden, por ejemplo, ser explotados para crear una retroalimentación tanto para estudiantes como para docentes, como una fuente adicional para la resolución de problemas o una hoja de trabajo o como una puerta de entrada a un juego didáctico. Las personas destinatarias usan sus teléfonos inteligentes para leer el código QR seleccionado. El código se refiere a un archivo que contiene los archivos de datos prediseñados y almacenados por su profesorado o el autor o autora de los materiales de aprendizaje. Los datos se explotan de acuerdo con las instrucciones del docente. De manera similar, un código QR puede vincular fuentes de información adicionales en una hoja de trabajo o para abrir la puerta del estudiante a la evaluación del curso / instructor. En el documento, ejemplificamos este enfoque utilizando ejemplos de diversos campos de Matemáticas, Estadísticas y Bases de datos. Finalmente, se discuten las ventajas y desventajas de este enfoque.

Palabras clave: código QR, tecnología educativa, aprendizaje móvil, educación a distancia